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THE GEMMULE *VS.* THE PLASTIDULE AS THE ULTIMATE PHYSICAL UNIT OF LIVING MATTER.[1]

BY JOHN A. RYDER.

AS is well known to every well informed person, *protoplasm* is now regarded as the substance which enters universally and constantly into the composition of the living form-elements or cells of all living things. It is, therefore, the material basis of life. All the varieties of organic structure, no matter how different from each other, have been primarily differentiated from apparently homogeneous protoplasm. Premising, therefore, that we understand that all histological differences presented by the tissues of living organisms arise by differentiations of, or secretions, derivatives of *plastids* (cells) primitively alike, we are ready to consider the theories advanced to account for the phenomenon of hereditary transmission. *Transmission* or *heredity* may be defined as that inherent tendency acquired from ancestry and manifested by developing or growing organisms to become essentially like, in appearance and structure, their immediate ancestor or ancestors, if the parentage be a sexual one. The appearance of a characteristic belonging to a remote ancestor in a new organism, which characteristic did not belong to its immediate ancestor, is said to be a case of reversion or atavism. This is explained upon the assumption—a rational one—that in the germinal matter, that is, a plastid, or an egg-cell or a sperm-cell or cells, if reproduction be sexual, derived from the immediate ancestor, may still inhere a tendency to develop characteristics belonging to the most remote of, an indefinite number of removes back, from such immediate ancestor. The tendency to develop such palæontological characters is supposed to remain in a latent or potential state in all those generations intermediate between the ancestor in which this characteristic was present and the young organism in which it has again made its appearance. In this way gradually but continuously, and adaptively acquired characteristics are transmitted, as well as habits. It may be that profound and enduring sensory impressions upon the maternal organism in higher forms, by their persistence, may produce immediate effects upon the offspring which cannot be attributed to ancestry. The many recorded instances in the human family of the effect of the so-called pre-natal influences would justify such an inference.

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[1] Embracing the substance of an essay read before the Microscopical and Biological Section of the Academy of Natural Sciences, of Philadelphia.

The phenomena of development presented by the embryological history of an organism, are serially or successively related to series of ancestral forms in a way which shows that the most remote ancestor was indubitably unicellular, for all beings commence their embryonic history as a one-celled egg, or as an egg-cell fused with one or more unicellular spermatozoöids. To this law no exception has ever been discovered. It passes at first by a process, then by processes, as complication is established by the former; not by leaps, but from one stage to the next higher, and so on in an absolutely continuous manner, so that it is impossible to mark the transitions, so that absolute *continuity* becomes a fundamental characteristic of the process of development.

It has also been noted that these successive stages, or a part of them, often represent, perhaps always within the limits of groups, a sort of recapitulation or successive shadowing forth, sometimes faintly, sometimes strongly, of the forms which appear to represent the phases through which the organism has passed in attaining its present form and structure. The process of development accordingly shows in a pronounced, or may be dim way, the types which have successively formed the starting points of its development in past time. A *phylum* or branch from the tree of life or chain of ancestors, is thus represented in its embryonic history. The being, in its evolution from the ovum, accordingly recapitulates the forms of its successively more and more complex, or more and more modified ancestral series—its palæontological history preserved in the rocks together with more or less note of its living cotemporary allies. The fossil forms of successive formations are frequently found to bear such a relation to the developing embryo. The rock record linked with the now living one is said to be the *phylogenetic* history, that is, it unfolds the history of the *phyla*, or branches of the tree of life. The history of the being or ontological history, therefore, becomes a more or less distinct record of the phylogenetic. In a word, *Ontogeny*, or the development of individual beings, is an epitome of the *Phylogeny* or phylogenesis of the race to which they belong.

This doctrine and its modifications is the motive force of modern *Biology*. Upon this ground, *Laplace*, *Lamarck*, *Wolff*, *Von Baer, Darwin, Spencer* and *Haeckel* have given to the science new impulses and aims far higher than possessed its masters in its infancy.

Dr. Darwin, in order to account for the phenomena briefly set forth in the above remarks, had recourse to what he called the "*Provisional Hypothesis of Pangenesis.*" The following is Mr. Galton's brief statement of the hypothesis:

1. Each of the myriad cells in every living body is, to a great extent, an independent organism.
2. Before the cell is developed, and in all stages of its development, it throws "gemmules" into the circulation, which live there and breed, each truly to its kind, by the process of self-division, and that consequently they swarm in the blood in large numbers of each variety, and circulate freely in it.
3. The sexual elements consist of organized groups of these gemmules.
4. The development of certain of the gemmules in the offspring depends upon their consecutive union through their natural affinities, each attaching itself to its predecessor in a natural order of growth.
5. That gemmules of innumerable varieties may be transmitted for an enormous number of generations without being developed into cells, but always ready to become developed, as shown by the almost insuperable tendency to feral reversion in domestic animals.

Galton, in order to test the truth of the foregoing hypothesis, transferred the blood of different breeds of rabbits from one to the other, actually establishing a cross-circulation, in which cases the blood flowing from one individual to another was practically unchanged. After this operation upon the animals, the young ones reared by these were not found to have been influenced in the slightest degree by the admixture of foreign blood with that already contained in the vessels of their parents, which should not have been the result were the hypothesis of *pangenesis* a true one. *Pangenesis* having been subjected to a crucial test and found wanting, nothing was offered, as an avowed substitute, until Haeckel proposed his *Provisional hypothesis of the Peregenesis of the Plastidule*, except by Prof. Cope, who, in his "Origin of Genera" (Proc. Acad. Nat. Sci., Phila., 1868), and afterwards in a paper entitled "On the Methods of Creation of Organic Types" (Proc. Am. Philos. Soc., 1871) more fully developed the views presented in the first mentioned. His views will be considered after Haeckel's have been discussed.

The *plastidule* of Haeckel is hypothetically the molecule of protoplasm, and therefore the simplest possible form in which protoplasm can exist as protoplasm. The theoretically high degree of complexity of the molecule of protoplasm renders it in the highest degree susceptible to influences brought to bear upon it by its environment. Primarily its atomic constitution C H O N, must be related in some way to its properties.

Haeckel attributes to every existing atom a modicum of force or energy as eternal and quantitatively unchangeable as the atom itself, which he calls the *atom-soul;* by aggregation of the atoms into chemical compounds, the mode and nature of the manifestation of individual atomic energies become mutually modified, and as resultants we have different properties and behavior manifested by such different compounds. By a long process of differentiation a compound was finally evolved answering in composition and properties approximately, or entirely, to existing protoplasm. This highly unstable matter, representing the aggregate or resultant of the energies of its component atoms as the energy of living matter, became the ancestor of some primordial amorphous being out of which, by adaptation and "survival of the fittest" the ancestors of the *Protista* became differentiated. On the principle that motion or impulses once imparted to bodies tend to be perpetuated in the absence of other interfering causes, the energy of movement, called life, once set going tended to be kept up, and in order that it could withstand the interference of a great variety af disturbing causes, it gradually acquired the power of adaptation. This adaptation being simply vibration of its molecules in unison with outer conditions as a resultant of those conditions. From the well known postulates in regard to the persistence of matter and motion, it is clear that the molecules of different masses, subjected to differing conditions, would gradually acquire different modes of molecular motion, which would tend to be persistent and perhaps approximately alike throughout the same mass. Any part of this mass broken off would tend to retain the molecular movements and consequently the properties of that of which it at first formed a part, but the new conditions to which it might become subject in the event of separation, render it probable that these motions might have others superadded, or the old ones so changed as to give rise to different phenomena. Different food, temperature, surrounding, media, etc., are thinkable as immediately active causes in the differentiation of the modes of molecular activity. Accordingly by the persistence of the type of molecular motion or motion of the *plastidule,* its characteristics tend to be exactly reproduced where reproduction is a process of mere division, as in the *Protista.* On the other hand, the motion of plastidule tends to vary as the surrounding conditions vary. Hence the difference in individuals arising from this adaptive power of the plastidule to accommodate its motions to the environment. Where the process of reproduction is sexual the fusion or blending of the products of the sex-glands to form embryos, there results a blending of the plastidular motion of the two. The characteristics of the resulting being is hence a resultant of two molecular modes of motion in the same way as the diagonal of a parallelogram of forces is the resultant of two more or less antagonistic forces. Putting this and that together, it is clear in what manner the characteristics of the offspring of sexual unions may come to preponderate in favor of the one or the other parent as the plastidular-molecular motion of the germ elements preponderates over that of the sperm element, and *vice versa,* thus mutually modifying each other in order to produce a resultant. It is also conceivable that the plastidular motions of remote ancestors as well as of approximal ones, tending to be persistent, may suddenly re-appear under favorable conditions, and that in this way there may arise a tendency to revert to such ancient progenitor. This hypothesis, if extended so as to conceive of the molecular vibrations of different stages of development as composing parts of a great molecular rhythm coeval with the first appearance of life on the earth, also explains the phenomenon of the recapitulation of *Phylogeny* and *ontogeny.* The tendency is to manifest the molecular motions in the order in which they succeeded each other in time. The registry or repetition in ontogeny being not always exact, it may be assumed that in the process of differentiation some of the types of vibration were in these instances irrecoverably lost.

Stated thus briefly, it seems to me unnecessary to enter into the account of the hypothesis of *perigenesis* further than to impress upon the mind of the reader that the vibrations of the plastidules are adaptive in character, that is, they are the resultants of outward conditions, represented hypothetically by X or any other unknown static or dynamic quantity. The theory is therefore purely mechanical and causal, and hence the word *perigenesis*—generated by surroundings. It seems to me that some form of hypothesis similar to this will be adopted unless the current views in regard to the physical constitution of matter undergo very great changes. It may be, if reports be true, that the so-called elements are not elementary, as Mr. Lockyer has been led to suspect from his spectroscopic researches, but even this will not destroy the essential elements of the problem, which are undoubtedly to be expressed in terms of matter and force without respect to what the nature of that matter may be.

Prof. Cope (l. c.) after discussing at length the evidence in favor of the correlation of life forces with the other physical forces and its conservation, goes on to particularize as follows: "Dr. Carpenter, in describing the correlation of physical and vital forces, defines the difference of organic species to be similar to that prevailing between different chemical bodies (the latter depending on different molecular and atomic constitution), which leads them 'to *behave* differently' from each other under similar circumstances. This may be more fully expressed by saying that different species possess different capacities for the *location* of the conversion of the physical forces into growth force." On this basis, "A 'descent with modifications' contemplated by evolution signifies a progressive change in this capacity." Applied to the explanation of his law of *Acceleration* and *Retardation*, he says: "*Acceleration* means an increase in this capacity; *retardation* a diminution of it." In other words, the undulations or vibrations of the molecules of different organisms and different parts of organisms differ in character, which is essentially the doctrine of Haeckel. He also speaks of growth force [energy] as cumulatively *potential* (p. 26). Its degree of potentiality he considers as marking the degree or grade of *grade influence* as manifested by successive higher forms. Grade influence is supposed to be the resultant of "effort and use" in the process, so that the static or dynamic environment and the organism are considered to be in a relation of retroactivity—in a state of interaction. At page 29, "Method of Creation," *On the transmission of Grade Influence*, the author admits: "How force potential in nerve structure is inherited through the reproductive elements is a great mystery," but he observes further: "In the spermatozoöids * * * growth force [energy] remains potential," that is, in a static condition, ready to be set free in the dynamic process of fertilization of the ovum, and of embryonic development. "Growth force potential in the spermatozoid, on its destruction [fusion with the egg] becomes converted into heat or other force. Thus may originate the growth force of the ovum, which, once commenced, is continued through the period of growth." It seems to me probable that the process of repetition is simply a phase of the manifestation of growth force as in the asexual fusion of growing cells, formation of spores in low plants and navicellæ cysts in *Gregarinæ*. It seems to me probable, also, that the cleavage of the yelk of the ovum supervenes just as soon as the static condition of its molecules is interfered with by blending with the spermatozoöid whose molecules are in a dynamical or potential condition as aforesaid. It is clear that if this is true, we get a composite result or resultant. In point of fact, this is tacitly implied where Prof. Cope says in continuation: "The process might be compared to the application of fire to a piece of wood. The force conversion is communicated to other material than that first inflamed." That is, the molecular movements of the embryonic mass, viz., sperm and germ, tends to be assumed by all the material which it appropriates to itself; this may be extended to the process of digestion or appropriation of protoplasm in animals and to the formation of protoplasm by plants when in growing conditions from binary and ternary compounds It is also clear that the quantitatively indefinite element x of the modifying environment of the plastidule is admittedly involved in consideration of the effect of *use and effort*, as held by this distinguished biologist, and that if use and effort are modifying causes, and molecular vibrations, whether they be in waves or ellipses or curves of any kind, will be influenced and accordingly modified. It must also necessarily be implied that these effects are persistent and that they involve the idea of *Perigenesis* quite as much as the plastidule.

The totality of the phenomena of *differentiation* and *reduction* (*specialization*, *cephalization*) in living forms, are, in view of the foregoing considerations, it seems to me, to be referred to dynamical causes. Laplace, from a mathematical standpoint, saw that this must be so. Lamarck, in his *Philosophie Zoologique*,[1] in the chapter VII, tom I, pp. 218–268, entitled, "*The influence of circumstances upon the actions of animals*," has some observations which show what a profound conception he possessed of the causal relations existing between the uses of parts and their development. Of recent authors, Darwin must occupy the first place, as many of his hosts of facts are admitted by him to bear a more or less distinctly dynamico-causal interpretation (*vide, Variation of Animals and Plants under Domestication*). By far the most comprehensive principles of dynamical biology have, however, been suggested by Herbert Spencer,[1] and they must be regarded as the first attempts at scientific presentation of the subject, in which, although the factors of the problem were not stated quantitatively in most instances, yet enough was said to show the applicability of the quantitative method. Besides these authors, more recent writers have begun to pay attention to the subject. Prof. Owen has for many years avowed his leaning to Lamarckianism. Prof. Jäger,[2] of Stuttgart, has written upon the influence of mechanical strains in determining the length, etc., of bones. Prof. Lucae, of Frankfort, a. M., has also contributed to this subject. Gegenbaur, in his "*Elements of Comparative Anatomy*," has numerous observations upon this subject. Prof. Cope may be added to this list, having contributed an article bearing solely upon this subject, to this journal, within the past year. This author, who, as we have seen, had already advanced views similar to Haeckel's, which, if not as clearly expressed, were nevertheless published more than five years previously. These names show that I have not been alone in the study of animal metamorphosis as produced by means of dynamical agencies. I have always held that both the organism by means of its voluntary acts and its passive surroundings reacted upon each other so as to produce morphological and consequently structural changes. My short essay, "On the Laws of Digital Reduction," which appeared in this Journal (Oct., 1877), and which was republished in the *Kosmos*, for 1878, illustrates what I have just said. My papers on the "Mechanical Genesis of Tooth-forms"[3] also show the application of the method, besides minor papers on the mechanical differentiation of certain portions of the vertebral column, in this Journal and Popular Science Monthly, 1877.

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[1] Nouvelle Edition, tom. I and II, Baillere, Paris, 1830.

The logical consequences of the acceptance of the Hypothesis of the Perigenesis of the plastidule, and with it the theory of dynamical differentiation—because the latter is no longer a hypothesis—forever relegates teleological doctrines to the category of extinct ideas. No matter how much our ideas may need to undergo modification, some similar hypothesis must eventually hold sway over the minds of biological thinkers, as the facts of science point in that direction and in no other.

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[1] *Principles of Biology* and also his *Principles of Psychology*.

[2] *Jenaische Zeitschrift*, Bd. V., 1869.

[3] *Proc. Phila. Acad. Nat. Sciences*, 1877, and the *Dental Cosmos*, 1878 (Etiological Addenda).

It has been suggested in conversation by my friend Dr. A. J. Parker, of this city, that the assumption of the *plastidule* as the ultimate physical unit of living matter was unnecessary, as it consisted merely in naming the protoplasm molecule, and it must be admitted that this view of the case is not without reason. Prof. Haeckel, it is to be supposed, however, adopted this name merely to distinguish his own provisional hypothesis from that of his acknowledged master. The word *plastidule* is a diminutive of the current word *plastid*, which is synonymous with cell, and therefor, implies and correctly, too, that the *plastids* are aggregates of varying numbers of plastidules, which are for physical reasons the smallest possible or conceivable units of living matter, of which even the most minute *gemmæ* or budding cells are composed.

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ABSORPTION OF WATER BY THE LEAVES OF PLANTS.

BY ALFRED W. BENNETT, M.A., B.S., F.L.S.

ALTHOUGH gardeners universally maintain that growing plants have the power of absorbing water through their leaves, both in the liquid and the gaseous form, in addition to the power of suction through the root, yet the contrary theory has been in favor during recent years among vegetable physiologists. The first recorded experiment, of any value on the subject, was about the year 1731 by Hales, as described in his "Vegetable Statistics;" the conclusion to which he came being that "it is very probable that rain and dew are imbibed by vegetables, especially in dry seasons." This result was confirmed by Bonnet in 1733. A century later, however, in 1857, Duchartre, experimenting on the absorptive power of plants, came, after considerable wavering, to the conclusion that rain and dew are not absorbed by the leaves of plants. This opinion has been, with but little exception, held by all physiologists during the last twenty years, notably by